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Current Sensing Unit

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Description

The invention relates to a current sensing unit for the potentially separate measurement of high direct currents in energy distributing facilities having nominal voltages of up to several kV. For example, this sensor can be used in an over-current relay for direct current high-speed circuit breakers.

So far, shunt isolation amplifiers, measuring devices comprising ferrite cores and Hall sensors as well as LEM converters have been used for measuring currents. These known devices, however, involve considerable disadvantages.

For instance, when current is measured by means of a shunt resistance, the current to be measured is led through a precision resistor and the voltage drop caused by the current is measured. This kind of measurement consumes unnecessary energy which contributes to the heating of the environment of the circuit breaker. Furthermore, this current measuring device is necessarily integrated into the current circuit to be measured, which affects the current to be measured itself; this is why the measurement is distorted more or less, depending on the size of the shunt resistor. Furthermore, in this way, no potentially separate measurement is possible when the voltages are high.

In the case of LEM converters, a ferrite core is arranged around a conductor the current flow of which is to be measured. Around this ferrite core, there is arranged a second coil by which a current is controlled such that the resulting magnetic field is adjusted to zero. In this way, a potentially separate measurement is possible, yet the cost of this kind of measurement is high.

By means of a Hall sensor, a magnetic field can be measured comparatively well with the Hall effect being utilized. A Hall sensor generates a voltage which is proportional to the magnetic field acting on the Hall sensor. This Hall effect occurring has a varying strength depending on the material used; the most advantageous ones are Hall sensors made from a semiconductor. Thus, by the Hall sensor, a magnetic field can be measured which is induced by a current flowing through a conductor. In this way, the current is measured in a potentially separate way.

However, since the voltage generated by the Hall sensor during the measurement is low and, under normal conditions, the magnetic field is subject to external influences, an amplification of the magnetic field is required; as a rule, this is achieved by ferrite cores. However, in this device, a non-linearity occurs due to the saturation behavior of the used magnetic cores. This leads to the disadvantage that the current can only be measured in a sufficiently exact way in a specific limited range, but the measured current outside this range strongly deviates from the actual current due to the saturation behavior. Furthermore, the cost of this measuring device is comparatively high due to the ferrite core.

In conclusion, the devices according to the prior art are disadvantageous in so far as, due to the saturation behavior, there occurs a non-linearity, the devices only have a minor electric strength, the devices give rise to comparatively high cost and, besides, have a high consumption of their own.

Thus, the invention is based on the object of creating a favorably priced current sensing unit which detects the current value in a potentially separate way, is

sufficiently precise and has a large degree of immunity to interfering.

This problem is solved by a current sensing unit as presented in the enclosed claim 1. This means that the current sensing unit according to the invention comprises at least two Hall sensors arranged on a conductor. The Hall sensors are arranged such that they detect a magnetic field generated by a current flowing through the conductor equally in absolute amount as well as an interference field equally in absolute amount, and detect either the magnetic field or the interference field with a different sign, respectively.

Further embodiments are specified in the subclaims.

Accordingly, the current measurement value is amplified either by an addition or a subtraction, yet an interference field due to external interference is eliminated.

By means of the current sensing unit according to the invention, it is achieved in an advantageous way that the current value detection can be carried out at low cost, since no additional ferrite cores are required. Also, a far-reaching lack of susceptibility to interference as well as a high isolation voltage can be achieved.

According to the invention, a current sensing unit for a simple electronic release trigger in the direct current range can be obtained, said current sensing unit detecting the current value in a potentially separate way for direct currents of up to 4 kV.

With reference to the enclosed drawing, the invention will be described in greater detail in the following by means of embodiments.

Fig. 1 shows a schematic representation of an over-current relay comprising a current sensing unit fixed to a conductor according to a first embodiment,

Fig. 2 shows an enlarged partial view of the representation according to Fig. 1, which shows the current sensing unit in greater detail,

Fig. 3 shows a current sensing unit according to a second embodiment,

Fig. 4 shows a block diagram of an evaluation circuit for a current sensing unit according to the first or second embodiment, and

Fig. 5 shows a block diagram of an evaluation circuit for a current sensing unit comprising four Hall sensors according to a third embodiment.

Fig. 1 shows a schematic representation of an over-current relay according to a first embodiment. The over-current relay comprises a basic switch BS and an arc quenching system LS, the exact function of which is, however, not important for this embodiment, so that no more detailed description thereof shall be given.

A current sensing unit SMA is fixed to a conductor 2. The current sensing unit SMA is based on the principle of the surface field measurement or the Hall effect, respectively.

The current sensing unit SMA according to the first embodiment is shown in greater detail in Fig. 2. There, two Hall sensors 1a and 1b are arranged opposite to each other on a part of a conductor 2.

Two Hall sensors 1a and 1b are used because the magnetic field is comparatively weak and is disturbed by interference from the environment, i.e. an interference field. To eliminate this external interference, the two Hall sensors 1a and 1b are arranged such that both Hall sensors equally measure the absolute amount of the magnetic field generated by the current flow, but measure the magnetic field with signs which are opposite to each other, respectively. If the amount of the current flowing through the conductor 2 is B, the Hall sensor 1a measures a magnetic field +B, for instance, whereas the Hall sensor 1b measures a magnetic field -B.

The output signals from the two Hall sensors 1a and 1b are subtracted. In this way, the interference field is eliminated from the output signals and the measured value of the magnetic field is amplified. Thus, it is not necessary to reinforce the magnetic field itself by means of e.g. ferrite cores as according to the prior art because the interference field is eliminated to the greatest possible extent by the subtraction of the signals and a strong measuring signal of the magnetic field to be measured is generated.

The measuring signal of the Hall sensor 1a shall be designated with MW1a, and the measuring value of the Hall sensor 1b with MW1b. If the two Hall sensors are arranged closely enough to each other, the interference field can be assumed to be equal at both Hall sensors. Thus, the results for the following measuring values are:

$$MW1a = +B + S$$
$$MW1b = -B + S$$

S here serves to designate the interference field. Thus, the subtraction of the two measuring values leads to the total measuring value MW:

$$MW = MW1a - MW1b = +B - (-B) + S - S = 2B$$

Thus, the interference field is extinguished and the use measuring value, i.e. the measured magnetic field, is doubled.

Alternatively, the two Hall sensors can be arranged such that each of them measures the whole measured magnetic field with different signs, i.e. the useful field B with the same sign and the interference field S with different signs. In this case, the interference field is extinguished by addition:

$$MW1a = B + S$$
$$MW1b = B - S$$
$$MW = MW1a + MW1b = 2B$$

As described above, it has to be observed for the arrangement of the Hall sensors that the probes have the shortest possible distance to each other, so that, if at all possible, the interference field is equal at the positions of the Hall sensors. Furthermore, it is important that the field strength is not affected by current displacement influences. In this connection, it is advantageous to arrange the Hall sensors on circular conductors. According to Fig. 2, e.g. the conductor 2 is designed as a circular conductor at the Hall sensors.

Both Hall sensors should be arranged at the same distance from the conductor 2 so that the two Hall sensors measure the magnetic field generated by the current flowing in the conductor equally in absolute amount.

Besides, the Hall sensors 1 can be arranged such that the conductor 2 extends between both Hall sensors 1, as is shown in Fig. 2. This arrangement is a possibility to arrange the Hall sensors such that they detect the magnetic field equally in absolute amount, but with opposite signs. Of course, other arrangements are conceivable, as well, e.g. an arrangement in which both Hall sensors 1 are arranged directly next to each other on one side of the conductor 2.

According to Fig. 1, the current sensing unit consisting of the two Hall sensors 1 is installed into a given conductor configuration such as, according to Fig. 1, in an over-current relay comprising the conductor 2 and the return conductor 4. Therefore, the Hall sensors 1a and 1b can be arranged and calibrated such that the influence of the return conductor 4 is taken into account, so that at least known interference is reduced due to the conductor configuration. The current sensing unit according to the first embodiment can, thus, preferably be used in a known and rigid conductor configuration.

In the following, a current sensing unit according to a second embodiment, which can also be used in an unknown conductor configuration, is described.

This current sensing unit is shown in Fig. 3. According to Fig. 3, the two Hall sensors are surrounded by a tubular

In the same way, the output signal from the Hall sensor 21 is supplied to a temperature compensation sensor 22, an amplifier 23, and an offset balancing arrangement 24. The signals are balanced against each other by the offset balancing arrangements 14 and 24, so that they can be supplied to a subtractor 5.

The subtractor 5 subtracts the two measuring signals from each other and outputs a resulting signal in which, as has been described above, the interference field has been removed. The output signal from the subtractor 5 is amplified by an amplifier 6 and is output to suitable further processing units. As examples, an over-current release 8 and a signal converting interface 7 are shown here. The over-current release can be a release as described in the first embodiment. The signal converting interface 7 e.g. outputs a current which is proportional to the measuring signal and e.g. ranges from 4 to 20 mA. Besides, further interfaces can be connected, as is suggested by the broken (dash) line leading to reference sign 9.

As has already been described above, the number of the Hall sensors of a current sensing unit is not restricted to two, but any number of pairs of Hall sensors is possible.

In the following, with reference to Fig. 5, an evaluation circuit for a current sensing unit comprising four Hall sensors according to a third embodiment is described.

In the representation, the same reference numbers correspond to the same components as in Fig. 4. This means that the two branches which are shown in the upper half of the representation and comprise the temperature compensation sensors 12 and 22, the amplifiers 13 and 23

and the offset balancing arrangements 14 and 24 correspond to the arrangement according to Fig. 4. The output signals of these two branches are subtracted from each other by a subtractor 51, which serves to extinguish the interference field. The output signal from the subtractor 51 is amplified by an amplifier 61 before it is supplied to an adder 15.

In addition to this arrangement, two further Hall sensors 31 and 41 are arranged on the conductor; these are e.g. shifted spatially by 90° as against the arrangement of the Hall sensors 11 and 21. Similarly as described above, the output signal from the Hall sensor 31 is supplied to a temperature compensation sensor 32, the temperature-compensated signal is amplified by an amplifier 33 and an offset balancing is carried out by the offset balancing arrangement 34. The output signal from the Hall sensor 41 is supplied to a temperature compensation sensor 42, the temperature-compensated signal is amplified by an amplifier 43, and an offset balancing is carried out by the offset balancing arrangement 44. The output signals of the offset balancing arrangement 34 and 44 are then subtracted from each other by a subtractor 52, the output signal from the subtractor 52 being amplified by an amplifier 62 before it is supplied to the adder 15.

The adder 15 adds the resulting measuring signals from the two pairs of Hall sensors 11 and 21 as well as 31 and 41. The sum signal is amplified by an amplifier 16 and then supplied to the further units 7, 8, and 9 as in the evaluation circuit according to Fig. 4.

According to the third embodiment, two pairs of Hall sensors have been used. As described above, also a higher number of pairs of Hall sensors may be used. The evaluation

circuit for such an arrangement may be constructed in a similar way as according to Fig. 5, with several signals then being supplied to the adder 15.

If the evaluation circuits according to Figs. 4 and 5 are modified, an arrangement in which the interference field is removed by an addition of the output signals, as mentioned in the description of the first embodiment, can be selected for the Hall sensors. That is to say that in this case the Hall sensors have to be arranged such that they detect the magnetic field generated by the conductor with the same sign, respectively, however the interference field with different signs. In the evaluation circuit the subtractor 5 according to the third embodiment then has to be replaced by an adder. In the variant of the evaluation circuit having two pairs of Hall sensors, the subtractors 51 and 52 have to be replaced by adders, respectively, according to the fourth embodiment.

Above, a current sensing unit based on the principle of the surface field measurement has been indicated. The current sensing unit comprises at least two Hall sensors 1a and 1b arranged on a conductor 2. The Hall sensors are arranged such that they detect a magnetic field generated by the current flowing through the conductor equally in absolute amount as well as an interference field equally in absolute amount, and either detect the magnetic field or the interference field with a different sign, respectively. Accordingly, the current measuring value is either amplified by an addition or by a subtraction, external interference by an interference field is, however, eliminated.